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Novice Importance Rules: Definitions and Equations

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for

Contracting Officer's Representative
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This research note indicates that novices judge importance in texts according to sentence type category (definitions, facts, equations, etc.). Subjects varying in expertise judged the importance of sentences in physics texts when these sentences were presented in one of two forms: 1) definitions or facts, 2) equations or verbal formulae. Experts and subjects without physics training judged these variants similar or equal in importance. However, beginning physics students judged definition and equation versions as more important.

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20. Abstract (continued)

Thus, sentence form is a salient text feature for beginning-level students who have developed general rules about what categories of information are important in physics. Sentence category is irrelevant for experts, who have rich content schemas allowing them to judge importance directly. Sentence category also has little effect on people without physics training, who lack strong expectations regarding what types of information are important. These results have theoretical implications for understanding content schema development and practical implications for textbook writers.

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Abstract

This study complements research indicating that content area novices judge importance in texts according to sentence type category (e.g., whether sentences are definitions, facts, equations, etc.). Subjects varying in expertise judged the importance of sentences in physics texts when they were presented in one of two forms: definitions or facts (Experiment 1), and equations or verbal formulae (Experiment 2). The two sentence versions were always identical in substantive content. Experts and subjects without physics training judged these variants similar or equal in importance. However, beginning physics students judged definition and equation versions as more important. Thus sentence form is a salient text feature for beginning-level students, who have developed general rules about what categories of information are important in physics. Sentence category is irrelevant for experts, who have rich content schemas allowing them to judge importance directly. Sentence category also has little effect on people without physics training, who lack strong expectations regarding what types of information are important. These results have theoretical implications for understanding content schema development, and practical implications for textbook writers.

Novice Importance Rules: Definitions and Equations

Diana Dee-Lucas & Jill H. Larkin
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Scientific textbooks are typically densely packed with complex information, including equations, symbols, and specialized terms. Consequently, it can be very difficult for students who are unfamiliar with scientific subject matter to distinguish the important content from the elaborative information when reading this type of text. The purpose of the present research was to investigate rules used by novice readers (i.e., readers who are unfamiliar with the text content domain) in determining what is important in scientific texts. The studies reported here tested the hypothesis that novices judge importance on the basis of category-membership rules -- that is, that they consider certain information to be important simply because of its category membership (i.e., whether it is a definition, equation, fact, etc.), regardless of its content. This was done by using minor wording changes to vary the category membership of selected information in physics texts, and examining how the category changes influenced experts' and novices' judgements of the importance of the content. Two experiments contrasted the judged importance of identical information when it was presented as a definition or a fact, and when it was stated as an equation or written out in sentence form.

There are various sources of information other than category-membership rules that novice readers could use in assessing importance. Most research has focused on how text-based indicators of importance such as text structure and signaling devices (e.g., underlining, adjunct questions, staging, typographical cuing, etc.) influence reading. These textual manipulations are "content-free," in that their effects should not depend on the nature of the text content or the expertise of the reader. In contrast, a "content-specific" source of information for assessing importance in texts is the reader's "content schema" (Kieras, 1985). A content schema consists of domain-specific knowledge about how information in a content area is typically organized, including what is important.

Past research has largely ignored the role of content-based schemas in the comprehension of novice readers. This is because it has typically been assumed that readers who are unfamiliar with the content domain of a text would lack such a schema (see Kieras, 1985, for discussion). However, recent work by Dee-Lucas and Larkin (1986) suggests that novices do develop a rudimentary "content schema" for scientific content domains. This content schema consists of rules specifying what types of easily-recognizable information (i.e., definitions, facts, equations, etc.) are important in physics texts. The current study examined the basis on which these rules are formed.

Novice importance rules have been investigated in research comparing the importance judgements of expert and novice physicists for different types of information in physics texts (Dee-Lucas & Larkin, 1986). Although this research found that experts and novices generally agreed on the relative importance of various types of information, the novices did not distinguish between the important and unimportant content within type categories. For example, both groups judged definitions to be more important than facts, but novices were even more likely than experts to judge definitions as important and facts as unimportant. This suggests that the novices had formulated a general rule that definitions are more important than facts and judged importance on this basis, without discriminating between important and unimportant definitions and facts. Unlike novices, the experts' importance judgements were not tied as closely to category membership. They presumably were judging importance on the basis of the nature of the specific sentence content, rather than the type category.

The findings from this area of research suggest that people just beginning to learn about physics develop a set of rules defining what types of information are important in that domain. They use these rules both in deciding what is important (Dee-Lucas & Larkin 1986) and in guiding attention during reading (Dee-Lucas & Larkin, 1987). However, this research on novice importance rules has not controlled for content differences between information categories. Therefore, the basis used by novices in deciding that one category is more important than another is not clear. Novices in these studies may have been basing their importance judgements on some feature of the content that differed between the categories, rather than on the categories themselves. For example, novices may have considered definitions to be more important than facts because the definitions contained more new terms. If this were the case, then the rule used by the novices would be that statements with new terms are more important than statements involving known terms, rather than a rule that definitions are more important than facts. Thus it is not known whether novices are judging importance according to a superficial analysis of category membership, or a "deeper" analysis of the nature of the information typically contained in various categories. A more precise understanding of the basis for novice importance rules would suggest how domain-specific content schema evolve in novice learners. It would also have implications for how text writers can effectively guide attention to important content in texts geared to a novice audience.

The current study examined the basis for novice importance rules. It specifically tested the hypothesis that novice importance rules are based solely on category membership; in other words, that novices consider certain information to be important simply because of its category membership, regardless of content. This was done by varying the category membership of specific information in physics texts, and examining how the category change influenced experts' and novices' judgements of the importance of the content. If novice importance rules are based on category membership, then novices should vary their assessment of the importance of a given statement with changes in its category. Experts, on the other hand, should be relatively uninfluenced by category changes because they would presumably judge importance on the basis of the nature of the content.

The category membership of sentence information was manipulated through minor wording variations which did not alter the primary sentence content, but signalled the content as belonging to a particular category. In this way, category membership could be varied by changing the form in which the information was presented while content was held constant. Thus unlike earlier studies, this research assessed the effects of category membership on perceived importance independent of category content.

Two studies were conducted in which expert and novice physicists judged the importance of information in physics texts. Experiment 1 compared the judged importance of attributive information when it was presented in the form of a definition or a fact. The purpose was to determine whether differences in the perceived importance of definitions and facts found in earlier research were due to differences in category membership as opposed to content differences. This was determined by contrasting the judged importance of information when it was signalled as being a definition, through the use of the words "is defined as", and when this signalling was absent or replaced with a neutral phrase so that the content appeared to be a fact. In this way the judged importance of definitions and facts was compared while holding sentence content constant across categories.

Experiment 2 extended the findings from the first study to a class of information which is particularly important in physics problem-solving -- quantitative relations. It contrasted the judged importance of quantitative relations when they were presented as equations (e.g., a = b/c) or written out in verbal form (e.g., a is equal to b divided by c). The equational form signals the content as being quantitative in nature, while the verbal form makes the category membership of the content less apparent. Previous research indicates that novices (as well as experts) consider equations to be a particularly important type of content in physics texts (Dee-Lucas & Larkin 1986). If novices are basing this judgement on a category-membership rule, (i.e., that equations are important regardless of content) then they would judge the same quantitative information as more important when it was presented as an equation rather than in verbal form.

In each study, two physics passages were used which contained target sentences that could be expressed in different forms. There were two versions of each passage, each version being identical except for the form in which the target sentences were presented. The importance judgements of the novices and experts for the fact and definition versions (Experiment 1) and the equation and verbal versions (Experiment 2) of the target sentences were compared to see to what extent the sentence form influenced the perceived importance of the information.

Experiment 1

The goal of this experiment was to determine if novices consider definitions to be more important than facts independent of the content of the two sentence types.

Method

Stimulus Materials. One passage was about work and energy and one dealt with fluid statics. Each was about 50 sentences long. One contained 9 target sentences and one had 11 target sentences.

The definition and fact versions of the target sentences differed in that definitions always included "is defined as," and thus were signaled as being definitions. In the fact versions, "is defined as" was dropped or replaced with "is represented as," "is calculated as," or "is indicated by." Thus the facts were "non-definitions" in that in place of definition signaling they contained phrases indicating that the sentence was presenting attributive information about the sentence topic (as opposed to criterial attributes defining the sentence topic).

Examples of the definition and fact versions of some of the target sentences are shown in Table 1a. There were two versions of each passage. In one version, the odd-numbered target sentences were definitions and the even-numbered were facts: in the second version this was reversed.

Insert Table 1 about here

Each of the target sentences was classified according to its level in the hierarchical structure of the passage. The procedure used for the structural analysis is reported in Dee-Lucas and Larkin (1986). This analysis produced a hierarchy with the main topics or concepts occurring at the highest levels and modifying information occurring at the lower levels. Modifying information consisted of examples, attributes and properties, derivations (i.e., information implied by or derived from higher level information), explanations, sub-topics, and preconditions (i.e., necessary conditions for a rule, principle, or fact to hold true). The hierarchical analysis was performed at the sentence level. There were 7 sentences at level 1 (the most superordinate level), 6 sentences at level 2, and 7 sentences at level 3. Hierarchical level was included as a variable in the data analyses to see whether perceived importance was influenced by level, and if this variable interacted with sentence form (i.e., definition or fact).

Subjects. The novices were 24 undergraduates with 2 or 3 semesters of college physics. Novices with this level of physics training were selected to insure that the novice group had had enough exposure to physics to have developed information-type rules, but had not approached the expert level in training. The 24 experts had completed at least one year of graduate study in physics.

Two control groups were also run in the experiment to see if expert-novice differences in the perceived importance of the target sentences were due to differences in educational level (i.e., undergraduate vs. graduate level training) as opposed to differences in physics knowledge. The two control groups were selected so as to differ in their educational level in the same manner as the two experimental groups. However, none of the control group subjects had taken any college-level physics, so they were similar to each other in terms of their physics knowledge. The undergraduate control group consisted of 24 undergraduates;

the graduate student control group consisted of people who had completed at least 1 year of graduate training in the humanities or social sciences. Although this group will be referred to as the graduate student control, it included some post-doctoral researchers and faculty. This was also true of the corresponding expert experimental group.

Although the control groups were specifically selected to control for educational differences, they would also indicate differences in perceived importance due to age, maturity, and verbal ability. In the case of verbal ability, it is reasonable to assume that graduate students in the social sciences/humanities would be as high in verbal ability as graduate students in physics. Similarly, it is likely that undergraduates attending the same university are roughly equivalent in verbal ability.

Procedure. The subjects were given one version of each passage. They were told to read each passage carefully, then rate the importance of each sentence on a scale from 1 (most important) to 5 (least important), and then indicate the 10 most important sentences in each passage. The instructions for the rating task indicated that each rating should be used at least once. All of the sentences were rated, but only the ratings for the target sentences were analyzed. The order in which the passages were read and the versions of the passages received were counterbalanced.

The novice and the undergraduate control groups were told that in completing the tasks, they were to indicate which sentences they thought would be most important to learn if they were going to be tested on the passage content. The expert and the graduate student control groups were told to pretend that they were teaching a course and indicate which sentences they thought were most important for their students to learn. These instructions match those used by Dee-Lucas and Larkin (1986) in their initial research on expert-novice differences in perceived importance. The instructions were designed to compare what novices think they should learn with what experts (their instructors) think novices should learn.

Results

The data from the two dependent measures were analyzed in two ways. The ratings data were analyzed using a multiway frequency analysis. This analysis fits a loglinear model to categorical data. The number of responses in each rating category (1 through 5) for each sentence type (definition and fact) occurring at each level (1 through 3) was tabulated for each of the subject groups. The multiway frequency analysis was performed on the total number of responses occurring in each of these cells.

The data from the sentence selection task (i.e., select the 10 most important sentences) were analyzed with a logistic regression. The variables entered in the analysis for each target sentence for each subject were sentence type (definition or fact), level (1 through 3), and subject group (novice or expert). The dependent measure was whether or not the sentence had been selected as one of the most important.

The data from the two control groups were submitted to identical analyses. The results of these analyses were compared to the results of the corresponding analyses of the experimental group data to determine if expert-novice differences were also reflected in differences between graduate students and undergraduates who had had no advanced physics training.

Ratings data: Experimental groups. The multiway frequency analysis of the ratings data indicated that the best-fitting model was a hierarchical model including the type x group interaction and the main effect of level ($X^2 = 23.80$, $df = 30$, $p < .78$). The mean ratings predicted by the model for the type x group interaction are shown in Figure 1a. The predicted means for the novices are 1.67 when the sentence was in the form of a definition and 1.89 when it was in the form of a fact. For experts, the predicted ratings are 1.79 for definitions and 1.82 for facts. This interaction indicates that novices were influenced in their importance ratings by the form in which the information was presented. They considered the same content to be more important if it was stated as a definition as opposed to a fact. The experts, on the other hand, did not appear to base their ratings on sentence form; there is very little difference in their predicted mean ratings for definition and fact versions of the target sentences.

Insert Figure 1 about here

The parameter estimates for the main effects and interaction for the complete model are shown in Table 2. Because of the usual constraints placed on the model, all parameter estimates for each main effect and interaction are constrained to sum to zero. Therefore, for all effects the magnitude of the parameter estimates for each variable are the same but in the opposite direction. The ratios of the estimates to the standard errors indicate the degree to which the parameter estimates differ from zero.

Insert Table 2 about here

The parameter estimates for the main effect of group show little difference between the experts and novices in their use of the five rating categories. The largest differences occurred in the use of rating 5 (the lowest rating) and rating 3 (the middle rating). The novices tended to use the rating 3 category more often than the experts (as indicated by the positive parameter estimate), while the experts tended to use the lowest rating more often than the novices. This suggests that the experts rated the target sentences lower in importance than the novices.

The parameter estimates for the main effect of type indicate that the largest difference occurred in the rating 3 category (the middle rating). The negative parameter estimate indicates that this rating was used more often with facts than definitions. There were also smaller differences in the use of the first two rating categories, with the definitions rated 1 or 2 more often relative to facts. This indicates that definitions were rated higher overall in importance than facts.

The type x group interaction estimates indicate that the greatest differences between experts and novices in rating definitions and facts occurred in the first two rating categories. The novices were more likely than experts to give a target sentence a rating of 1 if it was in the form of a definition, and somewhat more likely to rate it a 2 if it was in the form of a fact. The opposite was true for the experts, relative to the novices.

Level had a very strong influence on the target sentence ratings, as shown by the large parameter estimates for this effect. Level 1 target sentences tended to be rated as most important, indicated by the large positive estimate for the rating 1 category. The ratings for level 2 target sentences were spread over the categories without any strong clustering in any one rating; none of the parameter estimates for level 2 sentences differed from zero by more than two standard errors. Level 3 target sentences tended to be rated as 3 or 4 in importance, indicated by the positive parameters for these ratings categories. Level did not interact with type or group in influencing the ratings (i.e., including these effects reduced the fit of the model).

Ratings data: Control groups. The multiway frequency analysis of the control group data indicated that the best-fitting model included only the main effects of group and level ($\chi^2 = 28.64$, $df = 40$, $p < .91$). The inclusion of the type x group interaction or the main effect of type reduced the fit of the model to the data set. The mean ratings predicted by the model with the type x group interaction included are presented in Figure 1b for comparison with the corresponding experimental group means. As Figure 1b shows, there was no difference between the undergraduate and graduate controls in the influence of sentence type on the mean ratings of the target sentences. Additionally, the lack of a main effect of sentence type indicates that the form in which the target sentences were presented did not influence the control group ratings (i.e., they did not consider definitions to be important than facts).

The parameter estimates for the loglinear model including the main effects of group and level are shown in Table 3. The estimates for the main effect of group indicate that the undergraduates and graduates differed primarily in their use of ratings 1 and 4. The positive estimate for the undergraduates for rating category 1 indicates that they rated target sentences 1 more often than the graduate controls. The opposite was true for the rating 4 category, with the graduates using this rating more often relative to the undergraduates. This indicates that undergraduates rated the sentences as more important overall than the graduate controls. This effect is also apparent in Figure 1b.

Insert Table 3 about here

The pattern of parameter estimates for the main effect of level is similar to that obtained with the experimental groups. Level 1 target sentences were most likely to receive a rating of 1, indicated by the large positive parameter estimate for that rating. The ratings given to Level 2 target sentences were spread over the categories, with the strongest clustering in the rating 1 category (though this parameter estimate was much smaller than the rating 1 estimate for level 1 sentences). Level 3 target sentences were most likely to receive a rating of 4, with 3 as the next most frequent rating category for this level.

Ratings data: Summary. The results of the multiway frequency analyses indicate that novices base their judgements of the importance of text information on the category membership of the content. They specifically rate the same attributive information as more important when it is presented as a definition as opposed to a fact, as is shown in Figure 1a. Expert physicists are not influenced by category in rating importance, presumably basing their importance judgements on the nature of the sentence content. Similarly, the physics-naive control subjects are not influenced by signalled category membership, so that they appear to behave like experts in rating importance. This can be seen in Figure 1b. This is most likely because these subjects have no strong expectations about the relative importance of definitions and facts in physics texts, and thus are not influenced by this text feature. The lack of a type x group interaction in the control group data indicate that expert-novice differences in the perceived importance of definitions and facts are not due to differences in educational level.

Sentence selection data: Experimental groups. The sentence selection data were analyzed using a logistic regression. The regression analysis indicated that a good fit to the experimental group data was provided by a hierarchical model including the group x type interaction and the main effect of level ($X^2=8.69$, $df=7$, $p<.28$). This is the same model found to provide the best fit for the ratings data from the experimental groups. The predicted mean proportion of target sentences selected for the type x group interaction are shown in Figure 2a plotted on a logit scale. This interaction is very similar to the type x group interaction obtained with the ratings data. It shows that the novices were more likely to select a target sentence as important when it was presented in the form of a definition than a fact, while the experts were relatively unaffected by sentence form in their selection of the important sentences.

Insert Figure 2 about here

The parameter estimates for the complete logistic regression model are shown in Table 4. Unlike the estimates for the multiway frequency analysis, the logistic regression estimates show the size of the difference between the means for the two variables in an effect. Therefore only one parameter estimate is presented for each main effect (two for the interaction) and the ratios indicate the size of the difference between the two variables in each effect and interaction.

Insert Table 4 about here

The negative estimate for the main effect of type indicates that subjects tended to select more target sentences when they were presented in the form of a definition. This is consistent with the main effect of type found with the ratings data from the experimental groups. The estimate for the main effect of group indicates little difference between the experts and novices in the number of target sentences selected as important. The negative estimate indicates that the novices selected more target sentences than the experts. However, the parameter estimates for the two groups differed by less than two standard errors.

The type x group interaction estimates indicate that novices were more likely to select target sentences as important when they were in the form of a definition rather than a fact. Relative to novices, the experts were more likely to select the sentences when they were in the form of a fact. These findings are shown by the negative estimate for definitions and the positive estimate for facts.

The very large parameter estimates for the main effect of level indicates that this variable had a strong effect on which target sentences were selected as important. The negative estimate shows that target sentences from the upper levels of the passage hierarchy (level 1) were selected more often than the target sentences from the lower levels (level 3). This finding is also consistent with the strong levels effect found in the ratings data. As with the ratings data, level did not interact with sentence type or group in influencing sentence selection.

Sentence selection data: Control groups The logistic regression for the control group data indicated that the best-fitting model was a hierarchical model including the main effect of group and the type x level interaction ($\chi^2 = 1.78$, $df = 5$, $p < .88$). The inclusion of the type x group interaction reduced the fit of the model to the data. Thus there was no evidence that the importance judgements of the undergraduate and graduate control groups differed in the degree to which they were influenced by sentence type. This can be seen in Figure 2b, which shows the predicted mean proportion of definitions and facts selected by the two control groups plotted on a logit scale. These means are based on the model with the type x group interaction included.

The parameter estimates for the regression model including the effects of group and the type x level interaction are presented in Table 5. Unlike the experimental groups, level did not have a linear effect on the number of target sentences selected by the control groups. It was therefore entered into the analysis as a categorical (as opposed to a linear) variable, and separate parameter estimates were obtained for each level. The parameter estimates presented for the main effect of level represent the size of the difference between levels 1 and 2, and levels 2 and 3. For the type x level interaction, the parameter estimates indicate the size of the difference between definitions and facts at each level.

Insert Table 5 about here

The negative parameter estimate for the main effect of type shows that the control groups were more likely to select a target sentence when it was in the form of a definition than a fact. However, the type x level interaction indicates that the effect of type varied with level. The negative parameter estimate for level 1 indicates that facts were selected more often than definitions at the top level, while the positive parameters for levels 2 and 3 show that definitions were more likely to be selected than facts at the lower levels. The predicted cell means for this interaction are presented in Figure 3. Figure 3 shows that the main effect of sentence type is due primarily to a very large sentence form effect at level 3.

Insert Figure 3 about here

This finding suggests that subjects without physics training may tend to judge details (low-level information) in physics texts as being more important when they are presented as definitions than facts. However, this sentence type difference is based on very few data points, as most level 3 sentences were not selected as important. The mean number of sentences from level 3 selected by the control groups were 2.3 for the undergraduates and 1.6 for the graduates. *Additionally, this type x level interaction was not found in the ratings data for the control groups.* Therefore, it is possible that this particular effect is not replicable.

The negative parameter estimate for the main effect of group indicates that undergraduates selected more target sentences as important than the graduate control group. This is consistent with the finding in the ratings data that undergraduates tended to rate the target sentences higher in importance relative to the graduate controls.

The positive parameter estimates for the main effect of level indicate that averaged across sentence type, the number of sentences selected as important decreased with level. The size of the estimates show that the drop in the number of target sentences selected as important was much greater between levels 2 and 3 than between levels 1 and 2. This can also be seen in Figure 3.

Sentence selection data: Summary. The results of the sentence selection task analyses are consistent with the findings from the ratings data. Sentence category influenced the importance judgements of novices, with novices selecting more target sentences when they were presented in the form of a definition (see Figure 2a). Sentence category had very little effect on the sentences selected by experts. There again was no type x group interaction in the control group data, as shown in Figure 2b, indicating that expert-novice differences are not due to differences in educational level. Sentence category did have some influence on the judged importance of sentences for the control groups, in that they tended to select more of the definition versions than fact version from level 3. Thus it is possible that there is a bias towards considering low-level definitions as important in subjects who do not have scientific backgrounds

Experiment 2

Experiment 1 demonstrated that novice importance rules are based on category membership, and not content differences between categories. Novices specifically develop a rule that definitions are particularly important; as a result, they judge the same attributive information as more important when it is presented in the form of a definition. The purpose of the second experiment was to replicate and extend these findings by examining the influence of sentence form on the judged importance of quantitative relations.

Quantitative relations are particularly important for understanding physics in that they are central to solving problems. The ability to recognize problem-relevant quantitative information is essential for efficient problem-solving. However, quantitative relations vary in the manner in which they are presented in texts. They can be presented as equations, a form which explicitly signals the quantitative nature of the content, or they can be written out as verbal formulae. For example, the quantitative relation between a, b, and c can be expressed as "a = b/c" (an equation) or written out as "a is equal to b divided by c" (a verbal statement).

Efficient and accurate problem solving requires that the student identify those quantitative relations relevant to the problem, regardless of the form in which they are presented. However, the results of research with uncontrolled passages (Dee-Lucas & Larkin, 1986) suggest that novices may consider equations, like definitions, to be a particularly important category of information. That is, novices may have a rule that equations are particularly important (similar to their rule for definitions) which causes them to consider content presented in equational form as "automatically" important. If so, this importance rule could have important implications for novice problem solving performance. Novices could be biased in their assessment of the relevance of quantitative relations for problem solving depending on the form in which that information was presented. They would consider equations to be more important, and therefore more likely to be problem-relevant, than quantitative relations presented in verbal form.

Experiment 2 determined whether novices develop a category-based rule that equations are particularly important in physics texts. This was done by comparing expert and novice judgements of the importance of quantitative relations when they were expressed as equations or written out in verbal form. The purpose of the experiment was twofold. First, it provided a replication of Experiment 1 in support of the general finding that novices are influenced by sentence form in judging importance. Second, it extended this finding to a type of content which is central for problem solving as well as text learning in physics.

In the current study, experts and novices read passages containing target sentences which presented quantitative relations as either equations or verbal statements. Subjects rated the importance of each sentence on a 5 point scale, and selected the 10 most important sentences from each passage. The judged importance of the quantitative relations when they were presented as equations and verbal statements was compared to see if novices were influenced in their judgements by sentence form.

Method

Stimulus Materials. The two passages were about fluid statics, and work and energy. Each was approximately 50 sentences long and each contained 9 target sentences. Examples of the equation and verbal forms of the target sentences are shown in Table 1b. Symbols for quantities were used in both versions, but the relation itself was expressed symbolically in the equation form and written out in the verbal form. Thus the informational content was identical, and only the form in which the relation was conveyed (i.e. symbolic or verbal) differed. There were two versions of each passage. In one version, the odd-numbered target sentences were equations and the even-numbered were verbal statements; in the other version this was reversed.

As in Experiment 1, each of the target sentences was classified according to its level in the passage hierarchy. There were 6 sentences at each of the first 3 levels in the passage hierarchies. Level was included as a variable in the data analyses to determine if perceived importance was influenced by level, and if level interacted with sentence form (i.e., equation or verbal statement).

Subjects. The novices were 18 undergraduates who had completed 2 semesters of college physics. The 18 experts had completed at least one year of graduate study in physics.

Two control groups were again run to determine if expert-novice differences were due to differences in educational level rather than differences in physics knowledge. The undergraduate control group consisted of 18 undergraduates; the graduate control group consisted of 18 graduate students who had completed at least one year of graduate study in the humanities or social sciences. None of the control group subjects had taken any college-level physics.

Procedure. The procedure and instructions were the same as for Experiment 1.

Results

The data were analyzed in the same manner as the data from Experiment 1.

Ratings data. Experimental groups. The multiway frequency analysis of the ratings data for the experimental groups indicated that the best-fitting hierarchical model included the type x group interaction and the main effect of level ($\chi^2 = 17.81$, $df = 30$, $p < .96$). Figure 4a shows the mean ratings predicted by the model for the type x group interaction. As in Experiment 1, novices were influenced by sentence form while experts were not. Novices considered the same information to be more important when it was expressed as an equation as opposed to a verbal statement. The predicted means for the novices were 1.44 for the equation versions and 1.92 for the verbal versions. For experts, these means were 1.61 and 1.68 respectively.

Insert Figure 4 about here

The parameter estimates for the complete model are shown in Table 6. The estimates for the main effect of group show little difference between experts and novices in their use of the different ratings. Novices had a slightly greater tendency to use the rating 2 category relative to experts, while experts tended to use the rating 4 category more often, but the magnitude of these effects are not large (i.e., do not differ from zero by more than 2 standard errors).

Insert Table 6 about here

The estimates for the main effect of type show a large difference in the overall ratings of equations and verbal formulae. Equations were much more likely than verbal statements to receive the highest importance rating (rating 1), and somewhat less likely to receive a rating of 2 and 4. This indicates that equations were rated higher in importance overall than verbal formulae.

The type x group interaction estimates indicate that novices were much more likely to give a rating of 1 to equations than verbal formulae, and somewhat more likely to give low rating of 4 to verbal formulae than equations. The opposite was true for experts relative to novices.

The level parameter estimates again show that level has a strong effect on judged importance. Subjects tended to give level 1 target sentences a rating of 1, level 2 target sentences a rating of 2, and level 3 target sentences a rating of 4. Level did not interact with type or group.

Ratings data. Control groups. The multiway frequency analysis of the ratings data for the control groups indicated that the most appropriate model included the main effects of type, level, and group ($\chi^2 = 23.40$, $df = 35$, $p > .93$). The inclusion of the type x group interaction in the model reduced its fit to the data set. Thus the effect of sentence form on rated importance did not vary with level of expertise. This can be seen in Figure 4b, which shows the mean ratings predicted by the model with the type x group interaction included. The difference in the ratings of the equation and verbal sentence forms did not vary with the educational level of the control groups.

The parameter estimates for the model including the main effects of group, type, and level are shown in Table 7. The estimates for the main effect of sentence type indicates that sentence form did influence the importance ratings of the control groups. Equations were more likely to be rated 1 and verbal formulae rated 2. This can also be seen in Figure 4b, which shows that both groups judged information as more important when it was presented in the equational form as opposed to the verbal form. This was not the case in Experiment 1, in that the judged importance of the target content did not vary when it was presented in the form of a definition or fact. This indicates that there are general rules formulated by the population at large regarding the relative importance of different types of content in certain types of texts. In this case the physics-naive as well as novice subjects considered equations to be particularly important. However, as shown in Figure 4, the difference in the judged importance of equational and verbal statements was much greater with novices than controls, indicating that this general rule developed by physics-naive subjects is accentuated by limited physics training, and decreases with extensive physics study (as seen in the expert data).

Insert Table 7 about here

The estimates for the main effect of group show that there were large differences between the two groups in their use of ratings 1, 3 and 4. The undergraduate controls tended to rate the sentences either very high in the importance (1) or very low in importance (4), while the graduate controls were more likely to use the intermediate rating (3).

The estimates for level show the usual level effects. Subjects rated the top-level target sentences high in importance (rating 1), and low level sentences low in importance (rating 5). The ratings for level 2 sentences did not tend to cluster in any one rating category.

Ratings data: Summary. The ratings data comparing the judged importance of equations and verbal statements confirm the findings from Experiment 1. In both experiments, novices were sensitive to sentence form while experts were not. Specifically, when sentence information was signalled as belonging to a certain information category (i.e., definition or equation), novices rated that content higher in importance than when category membership was changed to that of another category, or made less prominent. This "form effect" reflects novice rules regarding the importance of different types of content in physics texts.

Unlike Experiment 1, the control group data showed that physics-naive subjects were also influenced by sentence form in the presentation of quantitative information. This suggests that there is a general consensus that equations are particularly important in science texts; such a consensus apparently does not exist for definitions. Note, however, that this initial preconception about the importance of equations is strengthened by a limited amount of physics training (see Figure 5a and b). The difference in the rated importance of the equation and verbal forms of the target sentences is much greater for novices than physics-naive subjects. The expert data additionally shows that after extensive physics training, subjects recognize the importance of quantitative information regardless of whether it is presented as an equation or verbal formula, and thus are not influenced by information form. The lack of a type x group interaction in the control group data again indicates that expert-novice differences are not due to differences in educational level.

Sentence selection data: Experimental groups. The logistic regression for the sentence selection data from the experimental groups indicated that the best-fitting model was a hierarchical model including the the type x group interaction and the main effect of level ($X^2 = 10.32$, $df = 7$, $p < .17$). This is the same model that accounted for the experimental group data from Experiment 1 and the experimental ratings data in the current study. The predicted mean proportion of target sentences selected for each group and type are shown in Figure 5a plotted on a logit scale. This interaction shows that novices are much more likely to select a target sentence as important when it is presented in the form of an equation as opposed to a verbal formula, while experts' sentence selection is not influenced by sentence category. This is consistent with the results of Experiment 1 and the ratings data indicating that novices are influenced by sentence form, while experts are not.

Insert Figure 5 about here

The parameter estimates for the logistic regression model are shown in Table 8. As in Experiment 1, these indicate the size of the difference between the means for an effect. The negative parameters for the main effects of type and group indicate that summed across groups, equations were selected more often than verbal formulae, and that novices selected more of the target sentences overall than the experts.

The type x group interaction estimates show that novices were more likely to select target sentences as important when they were presented as equations as opposed to verbal formulae. Relative to novices, experts were more likely to pick sentences in the verbal form, as indicated by the postive parameter for verbal formulae and the negative parameter for equations.

The large negative parameter estimate for level replicates previous results indicating that subjects are much more likely to select high-level sentences than low-level sentences as important.

Sentence selection data. Control groups The most appropriate model for the logistic regression for the control group data was a hierarchical model including the main effect of group and the type x level interaction ($X^2 = 7.02$, $df = 5$, $p < .22$). The inclusion of the type x group interaction resulted in a poorer fit of the model to the data. Thus the two control groups did not differ from each other in their evaluation of the importance of the equations and their verbal equivalents. This can be seen in Figure 5b, which shows the predicted mean proportion of target sentences selected for the type x group interaction, based on the model with the interaction term included. Figure 5b shows that both undergraduates and graduate students picked equations more often than verbal formulae. This is consistent with the results of the ratings data (shown in Figure 4b).

The parameter estimates for the regression model including the main effects of group and type x level interaction are shown in Table 9. As in Experiment 1, level did not have a linear effect on the number of target sentences selected by the control groups, and therefore was entered as a categorical variable in the analysis. The parameter estimates show the size of the difference between levels. The type x level parameter estimates indicate the size of the difference between equations and verbal formulae for each level.

Insert Table 9 about here

The parameter estimate for the main effect of type shows that overall the controls selected more equations than verbal formulae as important. However, the type x level interaction indicates that the effect of sentence form varied with level, with the largest difference between sentence types occuring at level 2. Figure 6 shows the predicted mean proportion of sentences selected for this interaction. The preference for equations can be seen for levels 1 and 2, with little difference in sentence type selection at level 3. Thus the general tendency for physics-naive subjects to consider equations as important may occur primarily for higher-level text information rather than text details. However, this interaction was not found in the ratings data and may in part reflect constraints imposed by the limited choice (i.e., pick 10) dependent measure. While many sentences were chosen from levels 1 and 2, relatively few sentences of any type were selected from level 3. Thus the lack of a difference at level 3 may be partly due to a floor effect.

Insert Figure 6 about here

The negative parameter for the main effect of group shows that the undergraduates tended to select more target sentences as important than the graduate students. This is consistent with the ratings data indicating that the undergraduates rated the target sentences more important overall than the graduate controls.

The two positive parameter estimates for level indicates that the controls selected more sentences from the higher levels than lower levels of the texts. The size of the coefficients show that summed across sentence types, the decrease between levels 1 and 2 in the number selected was roughly equal to the decrease between levels 2 and 3. This can also be seen in Figure 6.

Sentence selection data Summary The data from the sentence selection task again supports the findings from Experiment 1 that novices are sensitive to variations in sentence form when these variations signal specific category membership. Novices judged the same quantitative relations as more important when they were presented as equations as opposed to being written out in verbal form. Experts were not influenced in their importance judgements by sentence form.

As in the ratings data, the control subjects also considered the equational form of the target sentences to be more impor [illegible] effect was confined to the first two levels of the passage hierarchy in the sente[illegible] selection data This again indicates that physics-naive people also consider equations [illegible] be particularly important in science texts, and judge quantitative relations as more importar[illegible] when they are presented in this form. However, as with the ratings data, the influence of sentence form was much greater on novices than physics-naive subjects, indicating that this preconception is strengthened by limited physics training. In Experiment 1, there was not a general tendency for physics-naive people to view definitions as more important than facts (with the possible exception of a small effect for low level content). These findings suggest that there may be domain-specific category importance rules in the population at large, but these rules are weaker and possibly fewer in number than those generated by novices as a result of limited domain-related training.

Discussion

Although much research has examined the knowledge representations of experts, relatively little is known about the knowledge structures of novices. However, how novices represent unfamiliar content domains and the nature of the changes occurring in these representations has important educational implications for facilitating learning from text. Characterizations of the types of knowledge structures used by novices to govern text processing indicate how text should be structured, both globally and locally, to maximize the probability that novices will learn the important text content.

This study examined one aspect of novice knowledge representations -- rules for assessing importance in unfamiliar scientific domains. Previous research has shown that novices develop rules specifying what types of information are important in science texts. The current research investigated the nature of these novice importance rules. It provided a strong test of the hypothesis that novice importance rules are based on information-type categories, in that all variables other than information category were held constant. This was done by using minor wording changes to alter the category membership of sentences, and looking at how this changed their perceived importance.

The results indicate that novices are influenced by category membership in judging importance. Their judgements of the importance of content varies according to the form in which the content is presented. They consider the same attributive information to be more important when it is presented as a definition as opposed to a fact, and the same quantitative relations to be more important when they are presented as equations as opposed to verbal formulae. This "form effect" is not seen in experts, and is either absent or attenuated in physics-naive subjects. Thus novices are sensitive to variations in sentence form when these variations indicate membership in particular information categories.

These findings indicate that novice importance rules identified in earlier research using uncontrolled materials are based on category membership, and not content differences between categories. Thus, for example, novices judge definitions as more important than facts simply because they are definitions. However, similar differences observed in experts with uncontrolled materials do reflect content differences -- when the content of different categories is held constant, experts judge the same information presented in different forms to be equivalent in terms of its importance. This indicates that experts judge certain categories as more important than others because these categories typically contain the type of content that is important for understanding physics. For example, experts most likely consider definitions to be particularly important because it is necessary to fully understand physics terminology in order to understand the principles discussed in a text. Thus novices judge according to the information category itself (assuming that the content is important because of its category membership), but experts judge according to the importance of the specific content, which is correlated with certain information categories. The similarities between novices and experts in their importance judgements with uncontrolled texts are therefore based on qualitatively different analyses of the text content.

These findings suggest that people just beginning to learn about a content domain develop rules specifying what categories of information are important in that domain. The current research shows that novices specifically consider definitions and equations to be particularly important in physics texts. These rules are not inappropriate -- experts also consider definitions and equations to be important in naturalistic physics texts, indicating that definitions and equations typically contain information that is particularly important for understanding physics (Dee-Lucas & Larkin, 1986). However, the results of the current study indicate that novices judge importance on the basis of sentence type category without regard for sentence content. They judged the same content as more important when it was presented as a definition or equation, indicating that they consider these categories of information to be important regardless of their content. This suggests that information-type rules developed by novices are applied too rigidly, in that novices are not distinguishing between important and unimportant information within type categories. In this sense, novice rules are "overgeneralized." This overgeneralization results in novices systematically mis-identifying the important text content.

The results of the current research suggest how a content schema for a new knowledge domain might evolve in novice learners. A content schema indicates how the knowledge for a particular domain is typically structured, including what is important in the content area. The current study suggests that an early stage in the development of a content schema for scientific subject matter may be the specification of rules indicating what categories of information are important in that content domain. These rules could form the foundation for developing an expert content schema by providing a relatively undifferentiated base from which a more refined, hierarchical rule structure could be developed. In developing an expert content schema, novices would move from a classification system based on information categories to a more refined knowledge structure based on a deeper analysis of the nature of the category content. Starting with a novice schema composed of a few general category rules, novices could begin to differentiate the important and less important information within categories as they learn about the importance of specific content. In this way they could gradually move to a classification system based on commonalities among important content from various information categories. For example, novices could begin to view relational information as potentially important, regardless of its superficial category membership (i.e., whether it is specified as a fact, equation, definition, etc.).

This type of schema shift has been found by Chi, Feltovich, and Glaser (1981) and Schoenfeld and Herrmann (1982) in research on problem solving in physics and math. They found that novices classify physics and math problems on the basis of superficial characteristics of the problems, such as the objects and terms mentioned in the problem, and experts classify according to the underlying principles used in solving the problems. Additionally, Chi, et. al., found that subjects of intermediate expertise use both dimensions in their classification systems, suggesting that there may be a gradual evolution from the problem-features defined as relevant by novices to those used by experts. Chi, et. al., characterize this shift as moving from "surface structure" features to a "deep structure" characterization in analyzing physics problems. The results of the current study suggest that there is a similar shift in the text features viewed as relevant for assessing importance by novices and experts. Novices consider the surface-level feature of category membership as pertinent to judging importance; experts rely on a deeper analysis of the nature of the text content.

In some cases, novice importance rules may be extensions of general preconceptions developed before formal domain-related training. In the current study, the physics-naive control subjects as well as the novices thought that equations were particularly important, even though the control subjects had had very little physics experience. This finding for the control groups most likely reflects a general preconception about science texts derived from experience with a broad range of texts in this class. This suggests that the tendency to develop category-based importance rules may be a general phenomenon, probably occurring in most content domains having well-defined easily-identifiable categories of information. Although the development of these rules does not appear to depend on formal instruction, these initial general rules can be strengthened by limited formal experience within a particular content area. In the current research both control subjects and novices judged information as more important when it was presented as an equation, but the difference in the judged importance of equation and non-equation forms was much greater for the novices than the controls. Thus to the extent that these early general preconceptions are accurate (i.e., do reflect to a certain extent what is important in the domain), they appear to be accentuated by limited formal training in the field. It is also likely that general preconceptions which are inaccurate would be eliminated or replaced by such training.

Although the control subjects appear somewhat sensitive to sentence category membership, this sensitivity is not as consistent nor the effect as large as it is for novices. Thus the control subjects appear very similar to experts. This is most likely because they have few expectations about what types of information are important in physics texts, and those that they do have are not very strong (i.e., not as strong as for novice subjects). Thus the control subjects are not as strongly affected by sentence category because they lack a physics-relevant content schema; the experts are not influenced by sentence category because they have developed a much more refined schema which indicates the importance of specific information within the domain of physics. The experts' content schema includes a finer-grained analysis of the importance of physics knowledge than that captured by sentence-type categories.

This suggests an inverted U-shaped relationship among naive, novice, and expert physicists in their sensitivity to sentence category membership. Both naive and expert subjects are not influenced by sentence category to any large extent; they judge the same content equal or similar in importance regardless of its form. Novices, on the other hand, are "distracted" by form in their importance judgements in that they greatly alter their judgements according to the specified category of the content. This is because their knowledge of physics has caused them to develop specific expectations that certain information categories are more important than others (expectations that are weak or lacking in naive subjects) but they do not have sufficient knowledge to judge the importance of specific content within these categories (as experts can), and thus rely on these general sentence category rules.

A similar U-shaped relation has been found among beginning, intermediate, and expert radiologists in diagnosing x-ray pictures. Lesgold, Feltovich, Glaser, & Wang (1981; see also Lesgold, 1984) found that beginning residents and experts were better than intermediate-level radiologists in the diagnostic reading of certain classes of x-ray films. This is because accurate diagnosis involves an interaction between the physical features found on the x-ray and the radiologist's knowledge of the relevant contextual features which constrain the possible alternative diagnoses. Beginning-level radiologists base their diagnoses on the physical features of the x-ray, and are accurate when there happens to be a match between their interpretation of those features and the actual pathology; experts use their schematic knowledge to interpret the physical features in the context of other relevant information (such as the patient's medical condition), and thus are systematically accurate in their diagnoses. Intermediate-level radiologists possess some schematic knowledge, but this knowledge is not refined or flexible enough to provide accurate diagnoses -- it "distracts" them from the direct physical features used by beginners, and is not elaborate enough to allow them to pinpoint the appropriate alternative in the same manner as experts.

Thus both with physicists and radiologists, there is a stage in the development of expertise in which novices possess a primitive schema incorporating very general information about the domain (i.e., what categories of information are typically important for understanding physics; what contextual features are relevant for interpreting an x-ray). These schemas are not sufficiently refined to reliably allow accurate performance, and actually impair novice performance (relative to that of naive subjects) on certain tasks. Similar developmental trends have been found in the performance of children on a variety of cognitive tasks (see Richards & Siegler, 1982). These findings suggest that a short-term decrement in certain aspects of task performance may be a necessary consequence of the early forms of schematic knowledge that develop in the course of acquiring expertise in a variety of content domains

The importance rules developed by novices have important consequences for what novices learn from texts. Previous research has found that novices spend more time on information categories judged as important when reading physics passages, recall more information from categories judged as important, and include more information from these categories in their summaries of physics texts (Dee-Lucas & Larkin, 1986, 1987). Thus these information-category rules appear to influence novice readers' attentional processes during reading, as well as the macrostructure they develop for physics texts. These rules therefore determine in part what novices learn from these texts. The specific findings from the current research suggest that novices may be missing important facts and quantitative relations, and attending to some less important definitions and equations when studying these types of texts.

Additionally, this research suggests that novice rules may influence novice problem-solving performance, as well as what is retained. The ability to select from a text the relevant quantitative relations is crucial for skillful problem-solving. The finding that novices consider equations to be more important than verbal formulae suggests that novices may not readily recognize quantitative relations as being relevant in a problem-solving situation when this information is not presented in equational form. Similarly, novices may be more likely to attend to *irrelevant* quantitative relations when they are presented as equations. This inability to pinpoint problem-relevant information in a text would decrease the efficiency (and possibly accuracy) with which novices solve physics problems. Thus the nature of novice rules has important implications for novice problem-solving performance as well as text recall.

These findings suggest that certain variations in wording or form which do not affect the reading of experts or domain-naive readers will have essentially a "signaling" effect on novice attention and recall. Signaling involves the use of non-content words, such as "more importantly," "note that," etc., to emphasize particular text information. Signaling has been found to alter readers' attention, as indicated by differences in recall patterns for signaled and unsignaled texts (Loman & Mayer, 1983; Meyer, 1983). The results of the current study show that there are particular alternative wordings (e.g., "is defined as" vs. "is represented as") and presentation styles (e.g., symbolic vs. verbal) which do not function as signaling devices for most readers, but have a signaling effect for novices because they reflect the categorization scheme used by novices to assess importance. Therefore authors can unintentionally signal particular information as important through presentation selections of this type if they are unaware of novice preconceptions regarding the text content domain.

On the other hand, an author can use knowledge of novice importance rules in conjunction with signaling techniques to guide readers' attention to the appropriate text content. Writers can use signaling devices to emphasize important content within the sentence-type categories that novices consider unimportant, and de-emphasize less critical information in the categories that novices judge as important. Meyer (1975) describes four types of signaling techniques: (1) providing cues as to the text structure, as in "the problem is...the solution is," or "first...second...third;" (2) paraphrasing important text content before it is presented, such as "the important points in the following discussion are...;" (3) summary statements of key ideas presented after the relevant text; and (4) pointer words emphasizing specific statements in the texts, as in "more importantly," "it is notable that," "unfortunately," etc. These devices can be used independently of the overall hierarchical structure of the passage to emphasize specific content within each level, a technique that Meyer (1983) terms a "differential emphasis plan." These techniques have been found to be effective in altering recall patterns of readers of varying backgrounds and abilities (Loman & Mayer, 1983; Meyer, 1983).

Signaling devices can be used by writers of physics texts to help guide novices' attention to the important content. For example, the current study indicates that definitions are a type of content that is particularly salient to novices. Therefore, it would be helpful to novices if writers would differentiate the less important definitions from those that are central to the text. This could be done by including structural cues or preliminary summaries that emphasize the main topics or content that the author wants the reader to abstract from the text, and thus in effect "de-emphasize" unimportant definitions. This would help novices distinguish between the definitions that are to be learned (i.e., the main points) and those that are there to simply aid in comprehension or elaborate on the important points. Facts, on the other hand, are not particularly salient for novices, and novices may be missing important content of this type (Dee-Lucas & Larkin, 1986). In this case, the use of underlining and pointer words (e.g., note that, it is important to understand, this leads to the important conclusion that, etc.) could be used to draw attention to important facts.

Another technique that could be used to help novices distinguish between important and unimportant information is to teach novices a general learning schema that can be applied to texts to assess importance. This approach to manipulating attention and learning is "strategy-based" rather than "text-based." The ability of students to acquire general skills for learning from scientific texts has been demonstrated by Larkin and Reif (1976). They taught students a skill for understanding quantitative relations in physics texts by having students work through a series of training materials that required them to read physics texts and answer a prespecified set of questions. The subjects were able to learn to use this question set as a strategy for acquiring an understanding of new relations, and performed appreciably better on tests of understanding than subjects who had not acquired this learning strategy. In the case of the current study, the goal of the learning schema would be to help readers distinguish between important and unimportant information within categories typically viewed as unimportant, such as facts. For example, Larkin and Reif were able to specify a subset of facts (i.e., those dealing with units and typical magnitudes) that are particularly important for understanding quantitative relations. This type of schema could be used by novices in reading scientific texts to aid in identification of the important content within categories of information that they generally assume are unimportant. This schema would hold true for a broad content area within the domain of physics, but would most likely vary to some extent with subfields of study in physics.

The present study indicates that novice readers can be sensitive to very minor changes in wording at the sentence level in a text, in that these changes can be relevant to distinctions made in their content schema for the text domain. This suggests that writers need to be aware of the manner of presentation of information at a fairly local level in a text. In particular, experts writing for a novice audience will be most effective in enhancing learning of the important text content if they use text-based indicators of importance in conjunction with knowledge of their audiences' content schema. In this way, writers can use techniques such as signaling to provide novices with clear signals of importance which will help them distinguish between important and less critical content.

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Table 1: Sample target sentences

(a) Examples of definition and fact versions (Experiment 1).

1. Absolute pressure is defined as simply the actual pressure at a point.

   Absolute pressure is simply the actual pressure at a point.

2. Specific gravity is defined as the ratio of the density of a substance to the density of water.

   Specific gravity is indicated by the ratio of the density of a substance to the density of water.

3. In terms of this notation, the work ΔW done by a force $\mathbf{F}$ in moving an object through a displacement $\Delta \mathbf{r}$ is defined as

   $$\Delta W = \mathbf{F} \cdot \Delta \mathbf{r} = F(\Delta r \cos\theta)$$

   In terms of this notation, the work ΔW done by a force $\mathbf{F}$ in moving an object through a displacement $\Delta \mathbf{r}$ is represented as

   $$\Delta W = \mathbf{F} \cdot \Delta \mathbf{r} = F(\Delta r \cos\theta)$$

4. The unit typically used for measuring work, the joule, is defined as the work done by a unit force (one newton) acting on a unit distance (one meter).

   The unit typically used for measuring work, the joule, indicates the amount of work done by a unit force (one newton) acting on a unit distance (one meter).

5. Pressure is defined as the magnitude of a fluid force divided by the area of the surface on which it acts.

   Pressure can be calculated by dividing the magnitude of a fluid force by the area of the surface on which it acts.

(b) Examples of equation and verbal versions (Experiment 2).

1. Kinetic energy K is equal to the produce of one-half the mass m of the particle times the square v^2 of its speed.

   Kinetic energy is

   $$K = 1/2\ mv^2$$

   where m is the mass of the particle and v is its speed

2. The velocity **v** of an object is equal to the rate at which its position changes with time, or the displacement $\Delta \mathbf{r}$ divided by the corresponding time interval Δt.

   The velocity of an object is equal to the rate at which its position changes with time or

   $$\mathbf{v} = \Delta \mathbf{r} / \Delta t$$

   where $\Delta \mathbf{r}$ is the displacement and Δt is the corresponding time interval.

3. The gauge pressure P_g at a point in a fluid is equal to the difference between the pressure P_p at that point and the atmospheric pressure P_{atmos}.

   The gauge pressure at a point in a fluid is

   $$P_g = P_p - P_{atmos}$$

   where P_p is the pressure at that point and P_{atmos} is the atmospheric pressure.

4. Density ρ is equal to the mass m of a portion of material divided by the volume V of that portion.

   Density is

   $$\rho = m / V$$

   where m is the mass of a portion of material and V is the volume of that portion.

5. Specify gravity S is equal to the density ρ_s of a substance divided by the density ρ_w of water.

   Specific gravity is

   $$S = \rho_s / \rho_w$$

   where ρ_s is the density of a substance and ρ_w is the density of water.

Table 2: Parameter estimates, standard errors, and ratio of estimates to standard errors for a loglinear model of the ratings data from the experimental groups (Experiment 1). Asterisks indicate coefficients that differ from zero by more than 2 standard errors.

Effect	Coeff.	St. Error	Ratio: Coeff./St. Error
(a)Group: novice estimates (expert estimates are opposite)			
Rate 1:	.045	.066	.69
Rate 2:	.074	.075	.98
Rate 3:	.094	.090	1.04
Rate 4:	.019	.118	.16
Rate 5:	-.232	.182	-1.27
(b)Type: definition estimates (fact estimates are opposite)			
Rate 1:	.073	.067	1.10
Rate 2:	.082	.075	1.10
Rate 3:	-.224*	.090	-2.48
Rate 4:	.064	.115	.56
Rate 5:	.005	.192	.03
(c)Type x Group: definition estimates (fact estimates are opposite)[1]			
Rate 1:			
Novice (+)	.133*	.066	2.01
Expert (-)			
Rate 2:			
Novice (-)	.098	.075	1.30
Expert (+)			
Rate 3:			
Novice (+)	.003	.081	.04
Expert (-)			
Rate 4:			
Novice (+)	.014	.117	.12
Expert (-)			
Rate 5:			
Novice (-)	.052	.180	.29
Expert (+)			

[1]Parameter estimates indicate the size of the effect: positive and negative symbols indicate the direction of the effect for each group.

(d)Level

Level 1:			
Rate 1	.917*	.121	7.57
Rate 2	.214	.135	1.59
Rate 3	-.454*	.185	-2.46
Rate 4	-.504*	.250	-2.01
Rate 5	-.173	.351	-.49
Level 2:			
Rate 1	-.042	.110	-.38
Rate 2	.052	.120	.44
Rate 3	.140	.148	.95
Rate 4	.165	.193	.86
Rate 5	-.315	.320	-.98
Level 3:			
Rate 1	-.875*	.098	-8.97
Rate 2	-.265*	.104	-2.56
Rate 3	.314*	.128	2.46
Rate 4	.339*	.169	2.00
Rate 5	.488	.251	1.94

Table 3: Parameter estimates, standard errors, and ratios of estimates to standard errors for a loglinear model of the ratings data from the control groups (Experiment 1). Asterisks indicate coefficients that differ from zero by more than 2 standard errors.

Effect	**Coeff.**	**St. Error**	**Ratio: Coeff./St. Error**
(a)Group: undergrad estimates (grad estimates are opposite)			
Rate 1:	.323*	.065	4.98
Rate 2:	.083	.074	1.12
Rate 3:	-.070	.089	-.79
Rate 4:	-.323*	.117	-2.76
Rate 5:	-.010	.172	-.06
(b)Level			
Level 1:			
Rate 1	.695*	.105	6.62
Rate 2	.141	.119	1.18
Rate 3	-.302	.156	-1.94
Rate 4	-.492*	.220	-2.24
Rate 5	-.042	.282	-.15
Level 2:			
Rate 1	.128	.102	1.25
Rate 2	.013	.118	.11
Rate 3	.133	.137	.97
Rate 4	-.047	.188	-.25
Rate 5	-.226	.281	-.80
Level 3:			
Rate 1	-.822*	.092	-8.92
Rate 2	-.154	.099	-1.56
Rate 3	.169	.119	1.42
Rate 4	.539*	.155	3.48
Rate 5	.268	.226	1.19

Table 4: Parameter estimates, standard errors, and ratios of estimates to standard errors for a logistic regression model of the sentence selection data from the experimental groups (Experiment 1).

Effect	Coeff.	St. Error	Ratio Coeff./St. Error
Type:	-.414	.099	-4.18
Group:	-.186	.099	-1.88
Type x Group:	.236	.099	2.38
Definition (-)			
Fact (+)			
Level:	-1.016	.088	-11.49

Table 5: Parameter estimates, standard errors, and ratios of estimates to standard errors for a logistic regression model of the sentence selection data from the control groups (Experiment 1).

Effect	Coeff.	St. Error	Ratio: Coeff./St. Error
Type:	-.220	.098	-2.24
Type x Level:			
Level 1:	-.448	.139	-3.22
Level 2:	.014	.139	.10
Level 3:	.462	.140	3.30
Group:	-.590	.098	-6.02
Level:			
Level 1-2 diff:	.476	.139	3.42
Level 2-3 diff:	1.316	.140	9.40

Table 6: Parameter estimates, standard errors, and ratio of estimates to standard errors for a loglinear model of the ratings data from the experimental groups (Experiment 2). Asterisks indicate coefficients that differ from zero by more than 2 standard errors.

Effect	Coeff.	St. Error	Ratio: Coeff./St. Error
(a)Group: novice estimates (expert estimates are opposite)			
Rate 1:	-.016	.081	-.20
Rate 2:	.116	.098	1.19
Rate 3:	.003	.125	.02
Rate 4:	-.187	.182	-1.03
Rate 5:	.085	.205	.42
(b)Type: equation estimates (verbal estimates are opposite)			
Rate 1:	.297*	.083	3.60
Rate 2:	-.154	.098	-1.58
Rate 3:	-.031	.119	-.26
Rate 4:	-.195	.183	-1.07
Rate 5:	.083	.205	.40
(c)Type x Group: equation estimates (verbal estimates are opposite)[1]			
Rate 1:			
Novice (+)	.236*	.083	2.86
Expert (-)			
Rate 2:			
Novice (+)	.035	.098	.36
Expert (-)			
Rate 3:			
Novice (+)	.027	.120	.23
Expert (-)			
Rate 4:			
Novice (-)	-.256	.182	1.40
Expert (+)			
Rate 5:			
Novice (-)	-.042	.205	-.21
Expert (+)			

[1]Parameter estimates indicate the size of the effect; positive and negative symbols indicate the direction of the effect for each group.

(d)Level

Level 1:			
Rate 1	1.065*	.164	6.50
Rate 2	-.216	.200	-1.08
Rate 3	-.233	.249	-.94
Rate 4	-.461	.417	-1.11
Rate 5	-.155	.423	-.37
Level 2:			
Rate 1	-.087	.135	-.64
Rate 2	.352*	.154	2.29
Rate 3	.158	.191	.83
Rate 4	-.252	.323	.78
Rate 5	-.170	.348	-.49
Level 3:			
Rate 1	-.978*	.122	-8.01
Rate 2	-.136	.139	-.98
Rate 3	.075	.172	.44
Rate 4	.713*	.264	2.70
Rate 5	.325	.291	1.12

Table 7: Parameter estimates, standard errors, and ratios of estimates to standard errors for a loglinear model of the ratings data from the control groups (Experiment 2). Asterisks indicate coefficients that differ from zero by more than standard errors.

Effect	**Coeff.**	**St. Error**	**Ratio: Coeff./St. Error**
(a)Group: undergrad estimates (grad estimates are opposite)			
Rate 1:	.280*	.083	3.39
Rate 2:	.018	.099	.18
Rate 3:	-.301*	115	-2.63
Rate 4:	-.314*	.135	2.33
Rate 5:	-.312	.240	-1.30
(b)Level			
Level 1:			
Rate 1	.482*	.133	3.62
Rate 2	.036	.162	.22
Rate 3	.097	.172	.56
Rate 4	-.213	.227	-.94
Rate 5	-.402	.417	-.97
Level 2:			
Rate 1	-.001	.250	-.01
Rate 2	.067	.143	.47
Rate 3	-.100	.157	-.64
Rate 4	.052	.193	.27
Rate 5	-.019	.352	-.05
Level 3:			
Rate 1	-.482*	.110	-4.37
Rate 2	-.102	.133	-.77
Rate 3	.003	.158	.02
Rate 4	.161	.179	.90
Rate 5	.420	.303	1.39

(c)Type: equation estimates (verbal estimates are opposite)

Rate 1	.150	.078	1.92
Rate 2	-.181	.098	-1.84
Rate 3	.008	.103	.08
Rate 4	.104	.131	.79
Rate 5	-.082	.220	-.37

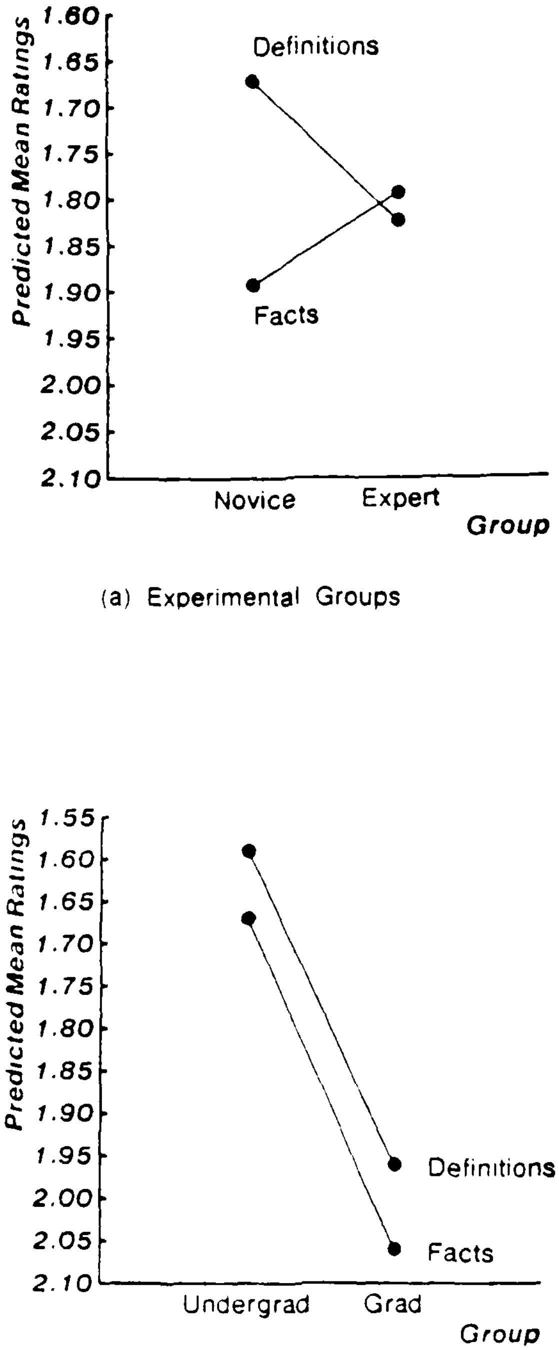
Table 8: Parameter estimates, standard errors, and ratios of estimates to standard errors for a logistic regression model of the sentence selection data from the experimental groups (Experiment 2).

Effect	**Coeff.**	**St. Error**	**Ratio Coeff./St. Error**
Type:	-1.100	.137	-8.03
Group:	-.530	.134	-3.96
Type x Group:	.842	.136	6.19
Verbal (+)			
Equation (-)			
Level:	-1.239	.126	-9.82

Table 9: Parameter estimates, standard errors, and ratios of estimates to standard errors for a logistic regression model of the sentence selection data from the control groups (Experiment 2).

Effect	Coeff.	St. Error	Ratio: Coeff./St. Error
Type:	-.544	.120	-4.52
Type x Level:			
Level 1:	.262	.176	1.49
Level 2:	-.652	.171	-3.82
Level 3:	.390	.165	2.36
Group:	-.756	.120	-6.28
Level:			
Level 1-2 diff:	.611	.174	3.51
Level 2-3 diff:	.530	.168	3.15

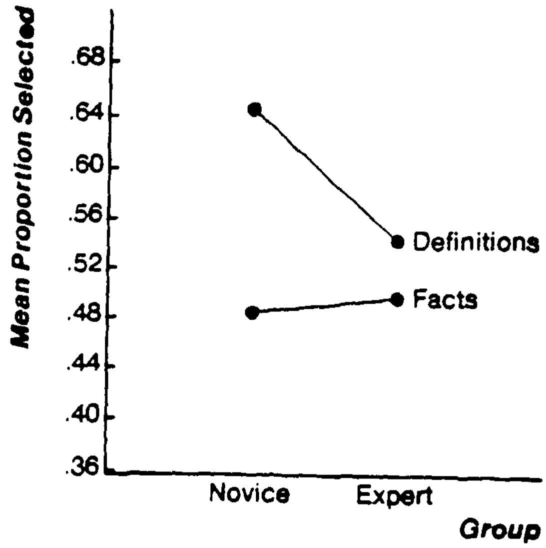
Figure 1: Predicted mean ratings for the type x group interaction in the ratings data (Experiment 1).



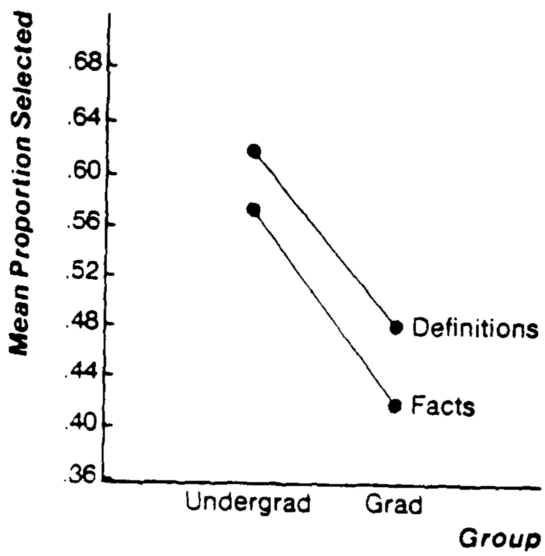
(a) Experimental Groups

(b) Control Groups

Figure 2: Predicted proportion of target sentences selected as important for the type x group interaction in the sentence selection data. (Experiment 1).



(a) Experimental Groups



(b) Control Groups

Figure 3: Predicted proportion of target sentences selected as important for the type x level interaction in the sentence selection data for the control groups (Experiment 1).

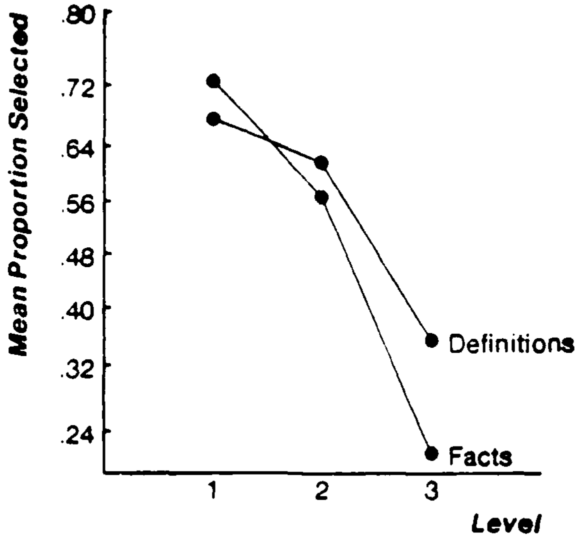
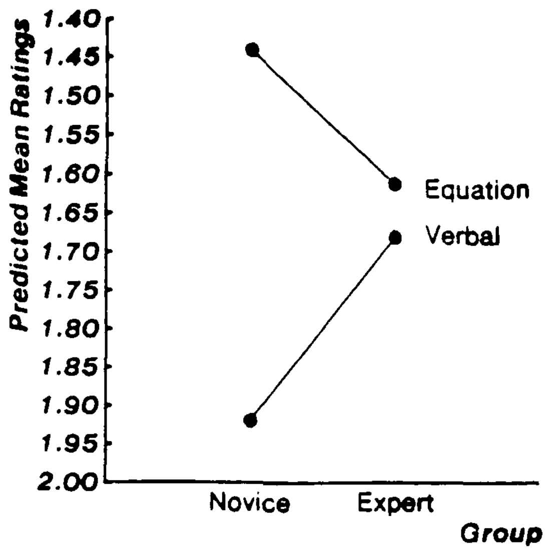
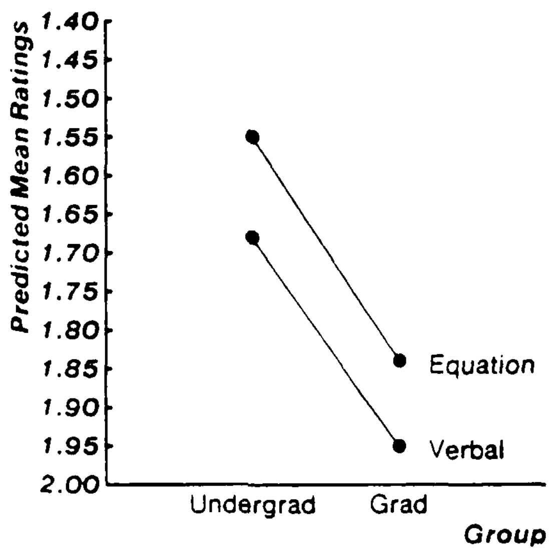


Figure 4: Predicted mean ratings for the type x group interaction in the ratings data (Experiment 2).

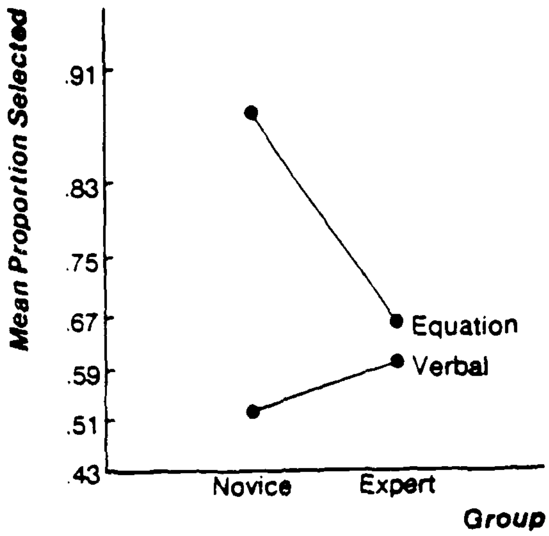


(a) Experimental Groups

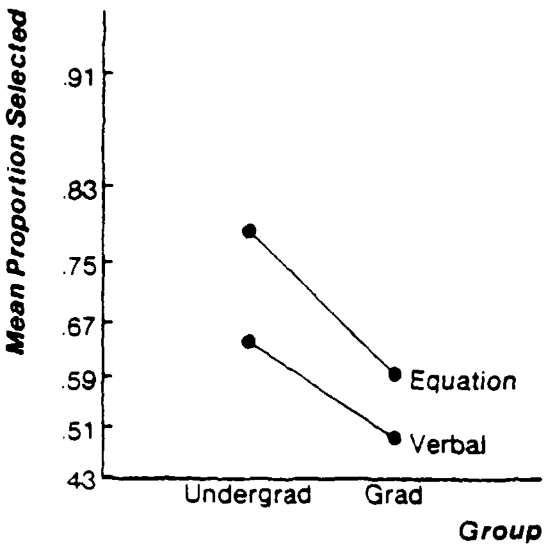


(b) Control Groups

Figure 5: Predicted proportion of target sentences selected as important for the type x group interaction in the sentence selection data (Experiment 2).



(a) Experimental Groups



(b) Control Groups

Figure 6: Predicted proportion of target sentences selected as important for the type x level interaction in the sentence selection data for the control groups (Experiment 2).